BLACK-FOOTED FERRET RECOVERY: A DISCUSSION OF SOME OPTIONS AND CONSIDERATIONS

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ABSTRACT.—A framework for recovery planning for the black-footed ferret (*Mustela nigripes*) is presented. Current species numbers are probably not sufficient to maintain long-term viability. Three options are presented for increasing ferret numbers: (1) increase available habitat for ferrets where they currently exist, (2) find more wild ferrets elsewhere, and (3) directly manipulate the ferret population through translocation and/or captive rearing. The first two options are either unlikely or currently unfeasible, making it necessary to initiate the third option to ensure ferret recovery. Even if additional ferret populations are located, option three should still be implemented. Three options for direct manipulation to increase ferret numbers and populations are discussed along with accompanying considerations. The captive-rearing/translocation option for species recovery is strongly recommended.

The Black-footed Ferret Recovery Plan (Linder et al. 1978) calls for the establishment of "at least one wild self-sustaining population of black-footed ferrets (*Mustela nigripes*) (BFFs) in each state within its former range." Currently, the species is known from a single population (43 adults in summer 1984, Forrest et al. unpublished manuscript) near Meeteetse, Wyoming. Our initial study efforts focused on evaluating and securing this single population and seeking other populations elsewhere (Clark 1984a). It is now time to address further the long-term goal of BFF recovery.

The purpose of this paper is to provide a framework for recovery planning based on current BFF knowledge largely derived from the Meeteetse studies. We present and discuss options available for increasing species numbers, specifically with regard to the Meeteetse BFF population, and some considerations for choosing among these options.

Background and Recovery Options

Because many states may not have sufficiently large prairie dog (*Cynomys* spp.) colonies to support BFF populations, it may no longer be possible or practical to meet the Recovery Plan goal of establishing BFFs in the 12 states within former BFF range. However, BFF recovery will certainly necessitate the establishment of several "self-sustaining" populations wherever they may be. What size might constitute a "self-sustaining" population has received much recent discussion. Shaffer (1981) defined a species minimum viable population (MVP) as the smallest, isolated population having a 99% chance of remaining extant for 1,000 years despite various natural and biological influences. He proposed five methods for determining MVP size: experiments, biogeographic patterns, theoretical models, simulation models, and genetic considerations. Groves and Clark (1986) evaluated the applicability of these methods to endangered species and the BFF in particular. They concluded that two methods are generally unsuitable to estimate BFF MVP size because of lengthy time period requirements (experimental methods) that provide little information for current conservation needs or because of extensive population data requirements (simulation models) that might necessitate too long and heavy a research impact on a critically endangered population. They found the genetic method of estimating BFF MVP to be currently most useful.

According to current genetic research, a minimum effective population of 500 or more animals is needed to guarantee the long-term genetic fitness of a species (Franklin 1980, Soulé 1980, Lehmkuhl 1984). Over the short-term (30 generations), a minimum effective population size of 50 should be sufficient to

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prevent an immediate loss of fitness in a population by keeping the increase in inbreeding per generation down to 1% (Frankel and Soulé 1981). Groves and Clark (1986) estimated that a MVP of 200 BFFs was necessary for maintenance of short-term fitness. They noted, however, that as more data become available, a combination of simulation and genetic approaches will likely produce the best MVP estimates, because additional important factors, such as environmental and demographic variability, can be incorporated. Indeed, Pettus (1985) has suggested that ferrets, as well as other carnivores and some large mammals, may be largely monomorphic, making genetic concerns for maximizing heterozygosity somewhat irrelevant (see Kilpatrick et al. 1986). This, and the fact that we have yet to note physical signs of genetic deterioration or senility in the Meeteetse population, does not guarantee that inbreeding problems will never occur. Carpenter and Hillman (1979) believed that inbreeding contributed to their lack of success in breeding captive BFF taken from the small South Dakota population in the 1970's.

Whatever method is ultimately used to determine BFF MVP, one fact remains certain: the single population of approximately 40 BFF adults is inadequate to ensure long-term population fitness and is dangerously vulnerable to natural catastrophes (e.g., plague or distemper outbreaks) because of its location on one prairie dog complex. Thus, it is imperative to increase BFF numbers without delay. We have three options for increasing BFF numbers: (1) increase available habitat at Meeteetse, (2) find more wild BFFs at other sites, and (3) directly manipulate BFF numbers, using either direct translocation or captive propagation/translocation of the Meeteetse BFFs.

Increasing Available BFF Habitat

Increasing available habitat (and therefore BFF numbers) at Meeteetse is biologically possible. The region contains several large, previously poisoned prairie dog colonies that could potentially be reconstituted by introducing prairie dogs. Increasing prairie dog habitat significantly will require several years (estimate 5+) and require additional management. Rancher approval of substantially increased prairie dog populations on their ranches is problematic. Such an effort would ultimately increase BFF numbers, but the single population would still be highly vulnerable to catastrophic elimination (e.g., plague, distemper). This option seems much less preferable to finding or establishing other BFF populations.

Finding New BFF Populations

Searches for BFFs throughout their former range has been underway in varying degrees for about two decades. Recently improved methods for locating ferrets (Clark et al. *Handbook of methods*, 1984; Clark et al. *Seasonality of black-footed ferret, diggings*, 1984) offer a better opportunity to discover additional BFF populations if they exist. Because none has yet been found despite new survey methods and increased survey efforts, we feel it is imperative to institute direct manipulation options to increase BFF numbers and populations. Field surveys should, however, continue to seek other populations throughout former BFF range.

Direct Manipulation of BFF Numbers

Direct manipulation options include translocation of some Meeteetse BFFs or captive-rearing these BFFs to build up numbers for later release to the wild. Translocation is the direct removal and subsequent release of animals from one area to another. Supporting arguments for translocation are: low manpower and equipment expenses, use of wild stock, and avoidance of long-term manipulation, such as captive propagation. Potential disadvantages include: depletion of the source population, need for large numbers of founder animals, high mortality expected among those animals, and lack of a captive reservoir of animals from which to control genetic variability, to insure against extinction, and to gather critical scientific data.

Past translocation efforts with other species have had mixed success and were typically accompanied by hazards and problems involving procedures, suitability of new habitat and release animals, human interest and dedication, and funds (Brambell 1977, Perry 1979, Campbell 1980, Temple 1983). Several mustelid species have been translocated, including fisher (*Martes pennanti*, Berg 1982), marten (*M. americana*, Berg 1982, Davis 1983, Fredrickson 1983), river otter (*Lutra*

TABLE 1. Notes from past mustelid reintroductions.

Reference	Animal	Period of release	No. animals released	Notes
Benson 1959	fisher	1955–?	6 M, 6 F	population established, Nova Scotia
Weckworth and Wright 1968	fisher	1959–1963	16 M, 20 F	successful, Montana
Williams 1962, 1963	fisher	1959–1963	20 M, 19 F	successful, Idaho
J. Thiebes (Berg, 1982)	fisher	1959–1963	10 M, 14 F	questionable, Oregon
Irvine et al. 1964; Petersen et al., 1977	fisher	1956–1963	78 M, 43 F	successful, Wisconsin, Michigan
C. Douglas (Berg 1982)	fisher	1956–1963	37 M, 60 F	successful, Ontario
Fuller 1975	fisher	1959–1967	19 M, 16 F, 89 unknown	successful, Vermont
Petersen et al. 1977	fisher	1966–1967	30 M, 30 F	successful, Wisconsin (more rapid than above)
Dilworth 1974	fisher	1966–1968	10 M, 15 F	no reproduction, New Brunswick
Pack and Cromer 1981	fisher	1969	6 M, 10 F, 32 unknown	successful, West Virginia
J. Hunt (Berg 1982)	fisher	1972	7 unknown	failed, Maine
R. Leonard (Berg 1982)	fisher	1972–1973	4 unknown	no discernible results, Manitoba
Burris and McKnight 1973	marten	1934–1952	10 M, 16 F, 32 unknown	several populations established, Arkansas
R. Leonard (Berg 1982)	marten	1954	24 unknown	uncertain, Saskatchewan
Jordahl 1954	marten	1953	5 unknown	unknown
C. Douglas (Berg 1982)	marten	1956–1963	155 M, 94 F	successful, Ontario
J. Stuht (Berg 1982)	marten	1957	12 M, 7 F	failed, Michigan
van Zyll de Jong 1969	marten	1960–1969	154 unknown (among 3 areas)	successful in two places, failed in one place, Manitoba
Schupbach 1977	marten	1969–1970	62 M, 37 F	no viable population in 1975–1976, Michigan
Davis 1983	marten	1975–1976	97 M, 27 F	no reproduction recorded by writing, Wisconsin
Frederickson 1983	marten	1977–1983	25 M, 17 F	survival appears high, South Dakota
Jameson et al. 1982	sea otter	1965–1972	708 unknown	three colonies appear successful (Arkansas, British Columbia, Washington), one will likely disappear (Oregon), and one failed (Arkansas)
Goodman, 1981	river otter	by 1981	8 M, 2 F, 45 unknown	success unknown, but sign noted after 18 mos, Colorado

canadensis, Berg 1982), and sea otter (*Enhydra lutris*, Jameson et al. 1982; Table 1). Successful transplants included the use of feasibility studies, solid rather than cage-type traps, the introduction of more than 30 animals (over one or more years), sex ratios favoring females, short handling and transportation periods, and an acclimatization period prior to release. To maximize success, releases were necessary over successive years.

BFF translocations have been poorly documented and offer little evaluation of success. Three BFFs (2M, 1F) were released in Wind Cave National Park in 1953 and 1954 (Garst 1954) after use in the Walt Disney film *Vanishing Prairie*. The last sighting of a BFF there was in 1957. Three BFFs were released on a prairie dog town in Cherry County, Nebraska, in 1957 but were not subsequently reobserved (Badlands National Park records).

Captive propagation takes selected animals into captivity for breeding purposes. Advantages of breeding endangered species in captivity have been discussed by Martin (1975), Carpenter and Derrickson (1981), Frankel and Soulé (1981), and Carpenter (1983) and include: development of a reservoir of animals to insure against extinction in the wild, pro-

TABLE 2. Table of data on black-footed ferrets held in captivity.

No.	Location	Number of animals	Sex	Age at capture	Time in captivity
1	Douglas, Wyoming	1	M	unknown	4 mos
2	New Mexico	1	F	unknown	5 mos
3	New York Zoological Park (NYZP)	1-02700	unknown	unknown	3 mos
4	NYZP	1-02699	M	unknown	1 yr 11 mo
5	NYZP	1-02701	unknown	unknown	3 mos
6	National Zoological Park (NZP)	1 (cat. 11,281)	unknown	unknown	2 yr 2 mo
7	NZP	1 (cat. 7803)	unknown	"young"	unknown
8	NZP	1 (cat. 7804)	unknown	"young"	3 yr 5 mo
9	NZP to London Zoo	1 (cat. 7805)	unknown	"young"	3 yr 8 mo
10	NZP	1 (cat. 7494)	F	unknown	2 yr 7 mo
11	NZP	1 (cat. 7802)	F	unknown	5 yr 1 mo
12	NYZP	1 ——	unknown	unknown	——
13	NYZP	1 ——	M	unknown	——
14	South Dakota	1	M	unknown	1 yr 7 mo
15	South Dakota	2	1 M, 1 F	unknown	unknown (short)
16	Patuxent	4	F	juvenile	"shortly"
17	Patuxent	1	M	juvenile	6 yr^{+}
18	Patuxent	1	M	juvenile	4 yr^{+}
19	Patuxent	1	F	juvenile	$^{-}$6 yr
20	Patuxent	1	M	adult	5 yr^{+}
21	Patuxent	1	F	adult	5 yr^{+}

duction of stock for release into the wild, collection of life history and behavior data unattainable in the wild but critical for future conservation and reintroduction efforts, and development of public education programs that will aid in enlisting support for rare animals. However, captive propagation efforts must also be seen as one part in the larger conservation effort, accompanied whenever possible by parallel programs for conservation of the natural habitat and the reestablishment of self-sustaining populations in the wild (Martin 1975, Durrell 1975, Warland 1975, Carpenter and Derrickson 1981). Potential disadvantages include: possible diversion of funds and interest away from habitat protec-

Year captured	Year died	Cite	Remarks
August 1953	released in Wind Cave National Park December 1953	Garst 1954	Warren Garst, keeper
December 1929	1930 (killed)	Aldous, 1940	Biological Service Collection 1210, caught during prairie dog gassing operations
received 10 April 1928	8 July 1928	NYZP record	Gift of W. J. Brunner
received 18 September 1903	19 August 1905	NYZP record	Gift of Mr. Beebe; remains at America Museum of Natural History (AMNH)
received 10 April 1928	6 July 1928	NYZP record	Gift of W. J. Brunner
received 19 September 1923, Pine Ridge, South Dakota	4 November 1925	NZP record	remains at U.S. National Museum (USNM)
received June 1910, Wallace, Kansas	prior to 30 June 1914—not reported	NZP record	
received 17 June 1910, Wallace, Kansas	26 November 1913	NZP record	no autopsy
received 17 June 1910, transferred 2 February 1911, received 16 February 1911, Wallace, Kansas	25 February 1914	NZP record, London Zoo record	
received 3 April 1909, Wallace, Kansas	2 November 1911	NZP record	USNM—skull; died of congestion of lungs
received 17 June 1910, Wallace, Kansas	2 July 1915	NZP record	remains at USNM
——	June 1888	AMNH record	remains at AMNH 2546-skin
spring 1905	June 1906	AMNH record	remains at AMNH 22894
caught June 1962; received USD 16 February 1963, Reliance, South Dakota	2 February 1964 at USD	Progulske, 1969	held 7 mo at mink ranch, then 1 yr at University of South Dakota
fall 1958, Faith, South Dakota	1 killed, 1 released	Henderson et al. 1969	
fall 1971, Mellette County, South Dakota	1971	Carpenter et al. 1976; Carpenter and Hillman 1979; Carpenter, personal communication	died from vaccination, live distemper virus
fall 1971, Mellette County, South Dakota	11 February 1978	"	died from neoplasia
fall 1971, Mellette County, South Dakota	1 July 1976	"	died from diabetes mellitis and complications
1972, Mellette County, South Dakota	2 October 1978	"	died from neoplasia
1973, Mellette County, South Dakota	9 April 1979	"	died from neoplasia
1973, Mellette County, South Dakota	2 January 1979	"	died from neoplasia

tion, depletion of the source population, and ethical and philosophical arguments against manipulating evolution or maintaining and manipulating wild animals in captivity.

Several mustelids have been successfully raised in captivity, including weasels (*Mustela nivalis*, Hartman 1964; *M. frenata*, Wright 1948), river otter (Johnstone 1978), Siberian polecats (*M. eversmanni*, Carpenter and Hillman 1979; Svendsen, personal communication), European polecats (*M. putorius* and *M. furo*, Buchanen 1966; Williams 1976), mink (*M. vison*, numerous mink ranchers), and marten and fisher (F. Gilbert, personal communication). Carpenter and Hillman (1979) attempted to breed BFFs at the U.S. Fish and

Wildlife Service's Patuxent Wildlife Research Center in the early 1970s and attribute their lack of success to genetically inferior stock. They are optimistic about the success of future captive propagation of BFFs using healthy stock. BFFs have been held in captivity for periods up to several years (Aldous 1940, Progulske 1969, Carpenter and Hillman 1979; Table 2). From this, it is highly likely that Meeteetse BFFs can be successfully maintained and bred in captivity. The following discussion examines direct manipulation options more specifically, applying current BFF knowledge to them.

Some Translocation and Captive-Rearing Options and Considerations

Some of the options to increase BFF numbers and populations are described below and include:

1. Direct translocation of BFF stock.
2. Captive-rearing of BFF in a controlled facility.
3. "Semiwild" field-rearing of BFF in outdoor enclosures.
4. Combinations of the above.

In addition, planning for each direct manipulation option requires addressing five major considerations:

1. Selection of animals for removal from Meeteetse to prevent drastic decline:
   - A. Number of animals to be removed.
   - B. Animal age and sex.
   - C. Time of year animals are captured.
   - D. Measures to be taken to ensure genetic variation among animals.
2. Assessment of rearing and release sites:
   - A. Size and location of site.
   - B. Status of prey base at translocation or field-rearing sites.
   - C. Disease and parasite vectors at new sites.
   - D. Predator management/control.
   - E. Release site security.
   - F. Time and resources needed to assess sites.
3. Captive facilities, animal care and costs:
   - A. Facility specifications, expertise, personnel, equipment, and costs.
   - B. Enclosures for animals and costs.
   - C. Dietary requirements for animals and costs.
   - D. Procedures to breed animals.
   - E. Procedures for care of new litters.
   - F. Commitment needed for facility.
   - G. Public education.
   - H. Time needed to establish facility.
4. Release considerations:
   - A. Methods—immediate or gradual.
   - B. Minumum numbers—age and sex.
   - C. Procedures to prepare captive animals physiologically and behaviorally for release into the wild.
   - D. Monitoring released animals—marking methods.
   - E. Long-term management needs for habitat and for maintaining genetic variation.
   - F. Local support and education.
   - G. Time needed to develop release stock.
5. Biological data:
   - A. Essential information needed for BFF recovery.
   - B. Biological data gained from any of the direct manipulation options.

Selection of Animals for Removal from Meeteetse

The major consideration in removal of BFFs from the Meeteetse population is maintaining a sufficient number of animals there to ensure continuation of that population. To do this, we must generally minimize removal of existing breeding stock (i.e., adults) and select adults and juveniles at a number less than that required for recruitment to maintain the current population.

Number of animals to be removed.—The number of BFFs removed from Meeteetse in any one year should be derived from ongoing research (litter counts, litter sizes, litter distribution, population estimates, age and sex data, mortality rates, etc.). A successful translocation must release enough animals each year to surpass animal losses to predation, dispersal, injury, etc. Berg's (1982) review of mustelid reintroductions emphasized that a minimum of 30 animals should be released to an area over a minimum of four consecutive years to ensure establishment of a new population. Temple (1983) suggested it may take even longer. We describe a hypothetical direct translocation scenario for removal of BFFs from Meeteetse below (Fig. 1).

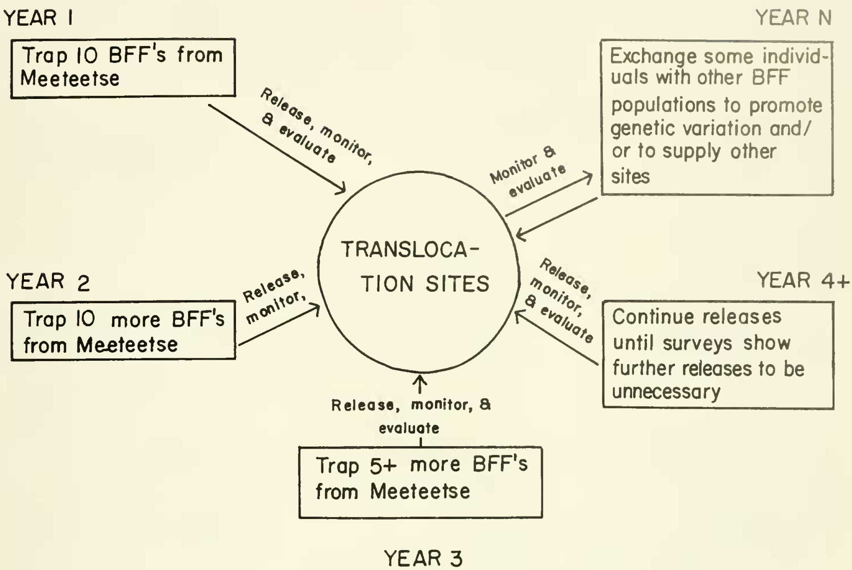

Fig. 1. Hypothetical direct translocation scenario for removal of black-footed ferrets from Meeteetse.

By contrast, fewer animals should be required overall to establish a captive BFF population, assuming breeding of ferrets is successful. Recommended numbers of founder individuals for establishment of captive populations range from five (Senner 1980) to 10 (Chesser et al. 1980) to 5–10 pairs (Foose and Foose 1982). Thus, it may be possible in a few years to have captive-reared surplus animals for release to one or more areas, requiring extremely low removal rates from the Meeteetse population. This may prove important if the population declines or if it is suspected that high numbers of juveniles are needed to counterbalance mortality factors and thereby ensure adequate population recruitment. A hypothetical captive-rearing scenario is presented below (Fig. 2).

AGE AND SEX.—Juvenile BFFs should probably be used in the direct translocation option, because this option involves potentially high post-transfer mortality and because inexperienced juveniles may be more "expendable" than experienced breeding adults. Conversely, we suggest that the first animals taken into a captive propagation program include at least two to three proven breeders, contingent upon maintenance of a satisfactory wild Meeteetse population size. Sex ratios should favor females for removal, possibly 2 or 3:1. We project a 2–3 year period is needed in a captive-rearing effort to perfect breeding techniques. Having only inexperienced breeders in hand may only compound difficulties in development of needed techniques, as well as delay production of captive and release stock. The mortality risk to captive individuals is assumed small, and, although separated from the wild population, they could be returned to it at any time if necessary.

TIME OF CAPTURE.—Juvenile BFFs should be trapped after weaning but while it is still possible to distinguish them from adults (late August to mid-September). There may also be advantages early in a captive-rearing program to trapping adult females after breeding in May to increase the probability of their bearing litters the first year in captivity. This would have to be weighed against the potential risk of trauma to these females.

MEASURES TO ENSURE GENETIC VARIATION.—With a direct translocation option, genetic varia-

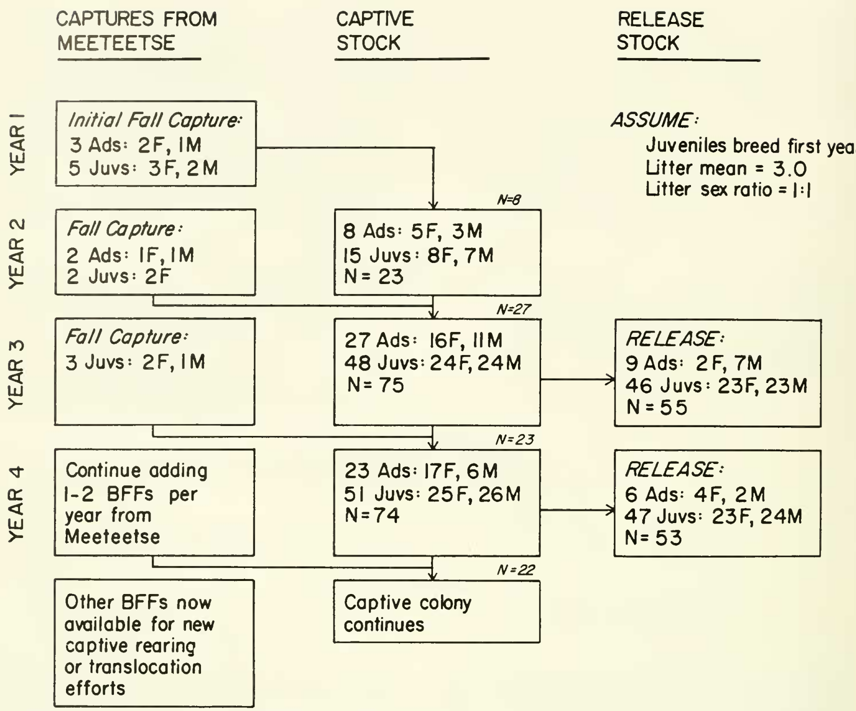

Fig. 2. A hypothetical captive-rearing scenario for black-footed ferrets.

tion could be ensured only by capturing BFFs from different parts of the Meeteetse complex to minimize relatedness. Selective breeding cannot be accomplished. However, future releases could introduce new genetic material to the release population.

By contrast, a captive propagation program permits selective breeding to maximize genetic variation and avoid inbreeding problems. Although it may eventually be decided that maintenance of heterozygosity is not as critical as environmental and demographic factors in maintaining population fitness, we should initially plan a strategy of genetic management. Foose and Foose (1982) describe a four-step general strategy for the genetic management of captive populations: (1) Acquire an adequate number of founders as unrelated and non-inbred as possible (from Meeteetse, this would mean from various parts of the complex); 5 to 10 pairs of unrelated and non-inbred founders would contain over 90% of the average diversity of a given gene pool. (2) Expand the population as fast as possible to facility(ies) carrying capacity to maximize the genetic contribution of each founder. This means that the short-term minimum effective population of 50 can be derived from a small number of founders as long as each one is well-represented in the expanding population. (3) Possibly subdivide populations between two or more facilities, closely regulating the exchange of genetic material among them. (4) Within any subdivisions, (a) maximize minimum effective population by maximizing number of animals that actually reproduce, (b) equalize founder representation, and (c) manage inbreeding coefficients. Franklin (1980) recommends the inbreeding coefficient be no more than 1% per generation.

Such a strategy should be adopted for breeding BFFs in both the captive-rearing or field-rearing options. This will help mitigate the double genetic bottleneck described by Temple (1983), which is caused by first choosing a small number of animals to be taken into captivity and second by taking only a selection of their offspring to be released. Studbooks should be maintained to record breeding histories (Mohr 1968).

Assessment of Rearing and Release Sites

SIZE AND LOCATION OF SITE.—Direct translocations or field-rearing with subsequent releases using BFFs from Meeteetse should first be considered on white-tailed prairie dog colonies (*Cynomys leucurus*). Behavioral differences of black-tailed (*C. ludovicianus*) and Gunnisons (*C. gunnisoni*) prairie dogs might potentially affect the success of BFFs raised on white-tailed colonies and translocated to colonies of other species. It is unknown whether captive-reared BFFs can equally adapt to the three prairie dog species. Eventually BFFs should be released to colonies of all three prairie dog species.

We suggest 40–60 ha/BFF be used to calculate size of translocation sites (Forrest et al. 1985). Black-tailed prairie dog colonies may possibly support a BFF on smaller areas because of their higher population densities, but currently we have no evidence for this. Ideally, any release site would be capable of supporting a minimum of 50 adult BFFs to allow for an initial rapid expansion of the population to minimize the loss of genetic variability (Chesser et al. 1980, Foose 1983) and to reduce the need and costs for genetic management (i.e., breaking up inbreeding groups and introducing new animals in future years). This would be 2500–3000 ha of active prairie dogs with a burrow density of 10+/ha (Forrest et al. 1985). However, smaller areas could be used in the overall recovery scheme if animals were occasionally mixed between populations. To achieve recovery, areas or combinations of areas supporting more than 500 BFFs will be required. Forrest et al. (1985) and Houston et al. (1986) discuss further details of BFF translocation site requirements.

Size considerations for a captive-rearing or field-rearing facility should be determined by space requirements per animal and the number of animals the facility should expect to hold (discussed below). Location of any such facility should seek to approximate or control for the environment of Meeteetse and have ready access to any necessary additional facilities or expertise not directly part of the captive-rearing facility (e.g., additional veterinarian, scientific, or technical staff, laboratory facilities, etc.). A field-rearing facility would be located on or adjacent to a release site, which may not have ready access to other facilities.

PREY BASE STATUS.—At least one season prior to any release or establishment of a field-rearing facility, status of the wild prey base should be assessed to ensure that it is healthy and viable. We suggest that monitoring of the prey base continue after releases as well.

DISEASE AND PARASITE VECTORS.—Prey should be screened for disease or parasite vectors, and plague potential should be assessed through local inquiry and examination of potential carriers. These precautions should also be taken on sites where fresh prey might be obtained to supply a captive-rearing facility.

PREDATOR CONTROL.—Short-term predator management should be considered at release sites. Removal of nearby raptor nests or perches and trapping and removal of badgers (*Taxidea taxus*), coyotes (*Canis latrans*), bobcats (*Felis rufus*), skunks (*Mephitis mephitis*), and foxes (*Vulpes* sp.) in the immediate area should be attempted. Predators, as well as excessive human disturbance, should be controlled at any facility housing captive animals.

RELEASE SITE SECURITY.—A major factor to consider when assessing release sites is obtaining long-term guarantees against prairie dog poisoning and extensive habitat alteration from landowners and/or agencies prior to the release. Grazing and some recreational land uses are acceptable.

TIME AND RESOURCES NEEDED TO ASSESS SITES.—Assessment of rearing sites for BFFs can probably be easily accomplished at relatively low cost and over one season. Initial assessment of release sites may take a couple of seasons, and obtaining necessary management agreements and protection guarantees could conceivably take longer. Cost and time of periodic site monitoring after releases must also be considered. It is critical that planning for translocation sites be done in conjunction with planning for captive-rearing facilities to make sure that release sites are available when suitable BFF stock has been reared.

Facilities, Animal Care, and Costs

FACILITIES.—Direct translocation will not require construction of a facility and is therefore the lowest cost option. Only holding boxes or cages will be needed during trapping, transportation, and release. Conversely, the captive-rearing option is certainly the most costly, and either requires building new or remodeling existing facilities with at least one permanent staff person. Any facility should include: (a) a food preparation and storage area, (b) an isolated quarantine area, (c) an emergency nursery, (d) various enclosures, (e) waste disposal and proper drainage, (f) water and electricity, (g) possibly a viewing area for the public, (h) a well-constructed boundary fence, (i) storage space for tools or equipment, (j) ready access to laboratory and veterinary facilities, (k) quarters for staff person(s). Frankel and Soulé (1981) remark that a consultant behaviorist familiar with the species (and closely related species) is mandatory to advise on which individuals should form the founding nucleus of the captive population and what enclosure "furniture" and structures will produce proper development and behavior, including proper hunting and escape behaviors after release.

For the field-rearing option, we envision a lower maintenance portable facility to be used over many years at successive sites, which would also require permanent staff. Costs would include site assessment, construction of a series of large, totally enclosed pens, staff salary, and veterinary and laboratory costs. A quarantine area, a storage area, and some access to veterinary and laboratory facilities would be needed. Many of the same costs are required as with a captive-rearing facility. The main difference here is that the facility is portable and has a lifetime dependent on the number of release animals needed for a particular site.

ENCLOSURES.—Like other mustelids, BFFs are typically solitary animals and should be kept in individual enclosures, except during breeding or when raising young. Enclosures for transporting animals and making direct translocations may be small plywood holding boxes with adequate ventilation and bedding. A proper lining is needed to prevent excessive BFF toothwear and breakage.

Management procedures have been described for BFFs kept at Patuxent Wildlife Research Center (Carpenter 1977, Carpenter and Hillman 1979, Hillman and Carpenter 1983). BFFs were housed in individual pens consisting of: (1) a two-compartment nest box that could be illuminated to permit observation through a one-way glass mirror, (2) a one-inch mesh welded wire intermediate area where food and water were provided and where defecation and urination generally occurred, (3) a wooden runway exercise area with an exercise wheel, and (4) a darkened artificial burrow below the exercise area. Facilities and equipment were routinely cleaned and disinfected. BFFs were housed alone in a well-ventilated pole barn-type building, fully daylighted and with clear plastic screened panels to protect against wind and cold temperatures.

Additional suggestions derived from observation of Jersey Wildlife Preservation Trust (Channel Islands, U.K.) procedures include a second nest burrow for choice and a variety of "furniture" in the enclosure providing various hiding places, variation in environment, and playthings. It is essential that BFFs have areas into which they can retreat and be assured that they are secure from any invaders or stressful conditions.

We have suggested a breeding stock of about 20 animals, ultimately providing about 50 release animals per year (Fig. 2). If one facility is used, it may have to house up to 70 BFFs at peak periods. We suggest dividing breeding stock among a few facilities to make better use of expertise at those facilities, to prevent catastrophic loss from disease outbreaks, and to reduce inadvertent selection from the rearing environment at any one facility. Several European ferrets (*Mustela putorius*) or Siberian ferrets (*M. eversmanni*) should be acquired to serve for experiments or as surrogate mothers.

For the field-rearing option, large pens would be used constructed of wire mesh, including a top, perhaps in a long rectangular shape, with a wire mesh bottom covered with about a 1 m soil layer. "Furniture" would be needed and perhaps a series of artificial burrows. Pens should be constructed to allow mixing of certain animals. Observation blinds and possibly an external light source should be considered to allow use of a starlight scope. Extra pens may be necessary to allow rotational use and cleaning. Size of the facility would be geared to the number of animals planned for release to that area.

DIET.—Animals at direct translocation sites may require a short period of feeding, including live prey from the new area. Ideally, food for captive animals should be as fresh and as natural as possible, especially considering that some animals will be returned or released to the wild. Live prey is certainly important for developing proper predatory behavior in young and can be used as a supplement for breeders and for variation from commercial diets. Progulske (1969) fed a BFF ground food consisting of jackrabbits, liver, meat scraps, fish, and dietary supplements. The animal did not eat dead small mammals even when the ground food was removed. Live prairie dogs were released on several occasions, which the BFF killed and fed upon. Carpenter and Hillman (1979) fed BFFs canned feline diet. Breeding diet was supplemented with fresh liver and small quail, and lactating females were provided with an artificial feline milk substitute. We presented dead prairie dogs to BFFs, as did Hillman (1968); they were quickly dragged down burrows. We have noted BFFs taking cottontail rabbits (*Sylvilagus nuttallii*), ground squirrels (*Spermophilus elegans*), and mice (*Peromyscus maniculatus*) as prey (Richardson et al., unpublished data).

Besides commercial diets, we suggest raising small mammals (rabbits, prairie dogs, mice, guinea pigs, etc.) adjacent to the facility (to minimize problems with parasites in the food) to supplement diets and for behavioral learning. At Jersey Wildlife Preservation Trust, whole carcasses are considered important in carnivore diets to provide psychological benefit to the animal (a carcass providing a variety of textures and gnawing surfaces) as well as nutritional benefit, even though costs for providing whole carcasses are higher than for commercial diets. Care should be taken in releasing live prairie dogs with BFFs, because we believe the prairie dogs are capable of inflicting serious injuries to some BFFs. Vitamin/carnivore supplements would be recommended.

PROCEDURES FOR BREEDING.—Breeding could not be controlled in the direct translocation option, but it would be in a captive-rearing option. Procedures for breeding BFFs in captivity have been discussed by Carpenter and Hillman (1979) and Hillman and Carpenter (1983). Females in estrus can be recognized by vulvar swelling and confirmed by vaginal smears. Carpenter and Hillman (1979) placed a male in with estrus females for two to three successive nights during the peak estrus period, removing him post-coitus. Observation blinds and starlight scopes were used to monitor and record behavior. At the Jersey Wildlfe Preservation Trust, individuals of normally solitary species are often allowed to mix during the breeding period through an opening between their enclosures (Nick Lindsay, personal communication). It is, however, critical that both animals have enough space to avoid interaction if they so desire, which in turn avoids aggressive confrontation. Initial mixings, at least, should be monitored, and the male would be closed out after the female has completed estrus.

Perhaps breeding procedures for the field-rearing option could consist of allowing the mixing of certain animals during breeding season, but in a large enough area to allow retreat to distinct living areas if the animals choose. We have observed male, female, and juvenile BFFs in close proximity (within 100 m of each other) for short periods of time. Intersexual mixing may not be a problem given an adequate opportunity for BFFs to retire from each other.

PROCEDURES FOR NEW LITTERS.—Carpenter and Hillman (1979) were concerned about preweaning losses from females failing to lactate or permit suckling, from mortality caused by the female, and from dietary or environmental factors. They planned to remove litters from their mothers after six weeks. They also observed that a European ferret readily accepted a BFF kit whose mother failed to lactate. It will have to be decided in both rearing options whether greater benefit will come from allowing litters more time with their mothers to approximate the wild condition or from minimizing preweaning losses by removing litters from females after a few weeks.

COMMITMENT NEEDED FOR FACILITY.—It is critical to ensure adequate commitment prior to initiation of any of the direct manipulation options, but especially for a captive-rearing facility, which would require the largest investment of time and funds. Various avenues for funding should be explored, one successful model being the Peregrine Fund. This is a nonprofit organization that provides funds for peregrine research and recovery efforts from private, state, and federal contributions.

PUBLIC EDUCATION.—A captive-rearing or field-rearing facility should strongly consider offering low-key public education programs to increase project support. This would be especially important in the field-rearing option, where animals would later be released to a nearby site. Programs should, of course, be tailored around the needs of the animals.

TIME NEEDED TO ESTABLISH FACILITY.—Facilities for direct translocation, requiring only cages or holding boxes, could be prepared in a matter of weeks. A captive-rearing facility may take from several months to a year to prepare. A portable field-rearing facility would require several months to acquire or construct its various components but should take a relatively short time to assemble once a site were chosen.

Release Considerations

METHODS.—Two release methods are generally used: "quick" and "slow." A "quick release" is the immediate release of an animal, with no time spent in a holding facility at the release site. A "slow release" means a gradual acclimatization to the new area, with the animal retained in a holding container or enclosure for a period of time, after which an entry is opened allowing the animal to leave at will. Supplementary feeding is typically done until the animal no longer frequents the release area. Berg (1982) has reviewed a variety of mustelid reintroductions and noted that the slow release method, holding animals up to five days, has been more successful.

NUMBERS.—We previously discussed BFF numbers to be released in a direct translocation. Ten BFFs would be an absolute minimum number (as in direct translocation) for an initial release, preferably 20 or more. Five or more animals would be added over a minimum of three years, unless subsequent releases are shown to be disruptive to established animals. A preferred sex ratio would favor females at about 2:1. Animals to be released should be old enough and experienced enough to be able to hunt successfully.

PROCEDURES FOR CAPTIVE-REARED ANIMALS.—If animals are directly translocated from Meeteetse, they will need little preparation for release other than a short acclimatization period. A health check (e.g., fecal screen) would be recommended prior to all releases.

With a captive-rearing or field-rearing option, some behavioral adjustment or training (e.g., to hunt and kill prairie dogs, to be wary of predators) may be needed to prepare stock for release. We presently do not know the degree to which young BFFs learn to hunt from their mothers and/or hunt instinctively. We have seen juvenile animals moving about with their mothers as if being taken on an exploratory or hunting foray. In any case, young BFFs should be proven hunters before being released to the wild. A procedure for this will likely have to be developed once the ferrets are in captivity, or possibly with a surrogate species.

MONITORING.—All released animals should be permanently marked, and some or all of the animals in the initial release and some animals in subsequent releases should carry radio-transmitters and be monitored regularly to best understand the fate of released animals and tailor subsequent releases for maximum success.

LONG-TERM MANAGEMENT.—A long-term management plan should be established not only to maintain the habitat quality of the area (as mentioned earlier), but also to assure the maintenance of genetic variation between different areas. Such a plan should be specified in advance of any release.

LOCAL SUPPORT.—In any area where BFFs will be newly released, an effort should be made to gain local public support of the project and to educate people about BFFs, their habits, and those activities that will directly or indirectly harm BFFs. This must be done in a low key manner within the sociological context of the release site (Clark 1984b).

TIME NEEDED TO DEVELOP STOCK.—The direct translocation option releases BFFs to the wild most quickly, with possibly two seasons needed to establish a site and capture the initial release stock. Time required to develop release animals from a captive- or field-reared stock will likely take a minimum of several years from initial capture, assuming about 10 BFFs are taken into captivity. As in direct translocation, releases of field-reared stock into one area should occur over a number of years.

Biological Data

What we will learn from translocating animals directly from Meeteetse, assuming at least some animals are marked, is the fate of some BFFs, some BFF movements at the new site, and possibly the breeding history of some females. It must be decided whether or not this is the minimum we need to know about BFFs in such a recovery effort.

Undoubtedly a much larger volume of biological data on BFFs could be gathered if some animals were held in captivity, specifically data on reproduction, parturition, feeding and nutrition, juvenile ontogeny and behavior, maternal care and behavior, defecation, activity patterns, genetics, prey acquisition and food habits, intraspecific behavior, intersexual behavior, age of sexual maturity, life-span, duration of sexual maturity, age at and behavior during weaning, sibling interactions, health, and disease. Most of this is currently poorly understood. Variation in cage design could allow for some observation of underground behavior, since as much as 80% of a BFF's activity occurs there. Techniques for artificial insemination of European ferrets and potentially for BFFs have been developed (Carpenter 1977) and may be considered here.

Less biological data on BFFs would be obtained with the field-rearing option because less control and handling of animals would occur. Observations of underground behavior would probably not be possible.

CONCLUSION

Assuming several, large new BFF populations are not found in the immediate future, the plan that best addresses the needs for BFF recovery must use a direct manipulation option (direct translocation or captive propagation/translocation). Certainly translocation should occur either directly or from a captive facility, because suitable BFF habitat still exists in many areas throughout the species' former range. We suspect that a direct translocation of BFFs from Meeteetse is unfeasible because of the direct risk both to the transferred animals and to the Meeteetse population itself if a large number of animals are removed. Captive-rearing of BFFs is probably the best recovery option because it would guarantee a protected reservoir of BFFs with a controlled lineage, because it would provide the greatest numbers of ferrets for eventual release over the long run, and because of the large amounts of information to be gained by close observation of the animals.

The field-rearing option may not allow close enough monitoring of BFF health and behavior or provide access to adequate support facilities and expertise, which the responsibility of taking an endangered mammal into captivity dictates. Such an option might be suitable for less rare animals or for BFFs once critical behavioral information and acceptable population size have been attained. The use of large portable outdoor enclosures may be suitable for some animals at captive-rearing or release sites.

Based on the above discussion, we recommend:

1. The first BFFs removed from Meeteetse be housed in a fully equipped captive-rearing facility.

2. A minimum of 10 BFFs be taken from the Meeteetse population over three to four years to establish the above facility, assuming population status there continues at previous levels; a small number of these should be breeding adults to expedite success of breeding efforts.

3. The goal of such a captive facility be to raise BFFs for future translocation to the wild; therefore, facilities and expertise should reflect the behavioral development of "wild-ready" BFF stock.

4. The breeding of BFFs in captivity and subsequent releases of BFFs to new sites be conducted in a way to maximize survival of these individuals as well as genetic diversity.

5. BFFs eventually be housed at more than one facility (perhaps three plus) to make better use of existing facilities and expertise, to insure against any catastrophic disease outbreaks at one facility, and to reduce any inadvertent selection due to the rearing environment at any one facility.

6. Translocation sites for BFF be large enough to support a viable short-term BFF population (currently estimated at about 50

adult BFFs) and be part of a managed network of sites that support a viable long-term BFF population (more than 500 adults).

7. A long-term time and resource commitment be made before BFFs are taken into captivity to ensure achievement of BFF recovery; a nonprofit organization, such as the Peregrine Fund Inc., is a suggested model for this.

8. A comprehensive management plan be developed prior to removal of BFFs from Meeteetse addressing facility development, timely designation of release sites, long-term monitoring of release sites, and long-term management of released BFFs. We suggest that strategic management follow the procedure outlined and discussed by Byars (1984). Strategic management includes both planning and implementation concerns. Byars (1984) presents an eight-stage process, including: (1) defining the mission, (2) formulating appropriate policies, (3) establishing long- and short-range objectives, (4) identifying strategic alternatives, (5) selecting the appropriate strategy, (6) developing an organizational structure, (7) managing organizational activities, and (8) monitoring the effectiveness of the strategy and organizational arrangements in achieving the objectives. Because these concerns are interrelated, considerable feedback must occur throughout the strategic management process.

Appropriate decision-making procedures are central to strategic management, and, in the uncertain task environment presented by ferret recovery, formal risk assessments must be a key feature (Behan and Vaupel 1982). Several time-related analytical and graphical techniques have been developed that can be useful in the strategic management planning process, including decision theory and critical path analysis (CPA) and program evaluation and review techniques (PERT). All these techniques use graphical networks to depict various segments of work that must be accomplished to complete a task such as ferret recovery. PERT methods may be more useful for ferret recovery strategic management because the activity durations are somewhat uncertain and variable (Behan and Vaupel 1982).

The future of this unique species is brighter today than in the last few decades. BFF recovery will require a cooperative private, state, and federal program and a closely managed coalition of interests.

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